3.6 Annex VI – Geothermal Energy Production and Use

Geothermal energy sources are of growing importance in China and have large potential, both for electric power production and for direct use for heating or cooling. The U.S. has developed leading geothermal technology and strong industrial interest in these areas. As a result, Annex VI to the Protocol on Cooperative Activities on Geothermal Production and Use, was signed on November 18, 1997 between the State Science and Technology Commission (now MOST) and the DOE. The objective of this agreement is to accelerate the utilization of geothermal resources in China, both for electricity generation and for direct thermal energy use. Forms of cooperation described in the Agreement include: planning and analysis of geothermal applications and resources, and scientific exchanges and visits.

China is a global leader and has rich geothermal resources with a long history of utilization in the use of geothermal resources for direct applications, with a thermal power contribution of more than 2,000 MW_{th} and a thermal energy production of more than 5,000 GWh in 1990 [5]. Hot springs have been used for space heating and for treatment of disease since the Ming Dynasty. Today there are 1,620 sites throughout China where geothermal energy is in direct use today [29]. In total, they have produced energy which is equivalent to burning 5 million tons of standard coal. Sites in operation include: 112 places for agricultural uses, 51 industrial applications, 65 sites using thermal springs for tourism, and 35 seismic observation stations.

Geothermal resources are spread widely across China. Evidence of abundant geothermal resources is widely spread around the country, including 2,500 thermal springs and 270 geothermal fields. Preliminary estimates are that recoverable reserves of geothermal energy are equivalent to 4.6 X 1,011 tons of standard coal [2]. Most of the hot springs are located in the Provinces of Fujian, Yunnan, Sichuan, and the Xizang (Tibet) Autonomous Region. High temperature geothermal resources are concentrated along the Himalayan Belt, which is an extension of the Mediterranean Geothermal Belt, passing through southern Tibet, western Sichuan and Yunnan, turning south through Thailand. The part of the Belt in China is extensive, more than 2,800 km long and 200-400 km wide. One of the best geothermal resources was found at one of the sites in the Yangbajain Field in Tibet (Figure 18), with a geothermal fluid temperature of 329.8°C at a depth of 2,007 m [30]. This is a good indication of the excellent mid- to high-temperature geothermal resources in the region.

Figure 18. Geothermal well drilling for the 10- MW power plant in the Yangbajain Field in Tibet

3.6.1 Technology and Application Descriptions

Geothermal energy systems use the conductive heat loss from the earth's interior to make steam, hot water, or with another heat transfer working fluid for direct use, e.g., building space heating/cooling, or to drive turbines to generate electricity. These two different geothermal applications are described below.

Geothermal Electricity Production

For thousands of years, people have benefitted from hot springs and steam vents, using them for bathing, cooking, and heating. During this century, technological advances have made it possible and economically practical to locate and drill into hydrothermal reservoirs, pipe the steam or hot water to the surface, and use the heat directly for space heating, agriculture, and industrial processes or to drive steam turbines to convert the heat into electricity. The reservoir temperature dictates the energy conversion process and also a significant driver in the economics. Only the high temperature, >200°C (392°F), and moderate temperature in the range >100°C and <200°C (212°F/392°F) geothermal resources are adequate for commercial power generation.

The total installed geothermal electric generation capacity is up to 29 MW and expansion is planned. Deep well, high temperature sources are used to make steam that is used to generate electricity at several geothermal sites. The largest site is the Yangbajain Geothermal Power Plant, located 94 km northwest of Lhasa the capital of Xizang Province (Tibet Autonomous Region). This plant has a peak capacity of 25 MW and has been producing about 100 TWh of electricity annually since 1979, providing about 50 percent of the electricity for the Lhasa grid [29 and 32]. In Yunnan Province another power generation project is underway and the first stage of public bidding will soon expand the drilling in the Hot Sea geothermal field located near Tengchong.

Geothermal Heat Pumps

Geothermal heat pumps (GHP) are a cost effective, energy efficient, and environmentally friendly way of heating and cooling buildings. They use the earth's relatively constant soil temperature to provide efficient year round heating and cooling. GHPs exchange heat with the earth through a system of buried plastic pipes called a ground heat exchanger. See Figure 19. In the winter, fluid in the pipes extracts heat from the earth, and carries it through the system and into the building. In the summer, heat is pulled from the building, carried through the system and deposited in the cool earth. Fans located inside the building distribute the warmed or cooled air throughout the interior, much like an air conditioner. GHPs save money in both operating and in maintenance costs. More than 70 percent of the energy required for heating and cooling comes from the earth.

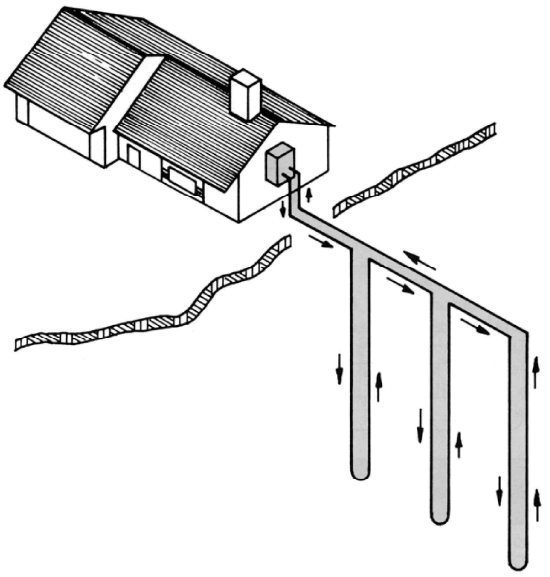

Figure 19. Schematic diagram of geothermal heat pump system for efficient building heating and cooling

Three geothermal heat pump demonstration projects are being developed to heat and cool buildings in Daqing (100,000 square meters), Shanghai (100,000 square meters), and Guangzhou (120,000 square meters), totaling 320,000 square meters (or 3.4 million square feet). Geothermal heat pump systems are likely to be economically attractive, energy efficient options, in virtually all of China. General agreements have been signed by three U.S. firms: Trane, Florida Heat, and Climate Master, to participate in these demonstration projects.

Geothermal Direct Use

China is also expanding the direct use of geothermal heat energy. Two demonstration sites have been established, one for building space heating and

supplying hot water in Xiongxian County, Hebei Province and the other is for plantation crop growing and fish breeding in Rucheng County, Hunan Province.

3.6.2 Geothermal Heat Pump Application Feasibility Study

Geothermal heat pump technology as the broadest range of potential applications. The technical issues and economic considerations for the various applications and geographic regions are not well understood. Further, China has various climatic zones which would use different types of heat pump systems. In the northern, cold climatic areas with an average temperature of -10°C to -30°C (14°F to -22°F) in winter, geothermal heat pumps can be use to supplement or replace coal-fired heating boilers. In the central, warm climatic area, primarily the Changjiang valley, winter temperatures range from -5°C to 10°C (23°F to 50°F), and is severely hot in summer with the temperature from 30°C to 40°C (86°F to 106°F). In this area, dual-purpose geothermal heat pump air conditioner systems could be used. Southern, subtropical climatic areas, including Guangdong, Fujian, Hainan, Guangxi, and Hong Kong are very hot in summer, with air conditioning needed seven months per year and is mild in winter, not needing space heating.

Studies are underway on the technical and economic feasibility of using geothermal heat pumps in the three climatic zones. The U.S. is providing technical assistance to China for the three geothermal heat pump demonstration projects in China.

The proposed demonstrations will address different functions and market areas in China. The plan is to have one site in each climatic region. The planned demonstration sites are:

- A commercial building complex in the city of Daqing that is in the northern climatic region of China
- Commercial projects will demonstrate the technology in the central climatic region of China in Shanghai, including a multistory commercial office building , used as the Center of the Shanghai Minhang Economic and Technology Development Zone, which is fully air conditioned by a geothermal heat pump system, and
- A large apartment and commercial building complex near the city of Guangzhou that is in the southern climatic region of China.

As China intends to purchase U.S. built geothermal heat pump units, the DOE plans to support this major investment by helping industry to provide technical support and training. Assistance may include project feasibility studies, technical training, and educational and joint project evaluation and management activities.

In a second phase under consideration, the study could address technical feasibility of applying geothermal heat pump technology, focusing on shallow ground water resource distribution, deep geothermal resource distribution, and open water resource distribution. This study could also address the benefits and risks of applying geothermal heat pump technology to improve environmental quality in China.

3.6.3 Tengchong Geothermal Electric Power Pilot Plant

Responding to a request for technical assistance, DOE sent two U.S. geothermal experts to the Tengchong Geothermal Project in China to study drilling equipment, safety, and geological issues. The drilling expert reported that the drilling crew in Tengchong is very experienced in oil and gas well drilling to the projected depth, but they lack experience in geothermal drilling procedures. In some cases proper

equipment, materials, and tools needed for this type of drilling were not available or were not being used correctly. Specific recommendations were made to the Chinese drilling team that should improve operational safety. It was also concluded that specialized drilling equipment was needed, is commercially available, and could significantly reduce the cost of drilling. The geothermal exploration expert reported that the site of current drilling may be too far away from the resource to have useful fluid temperature or flow rate. Suggestions were made for using other nearby sites with greater rock fracturing and expected higher temperature water that could be better commercial sites. To assist China in completing the first 10-MW geothermal pilot project at Tengchong, the U.S. experts recommend the following: (1) geologic and geophysical assistance; (2) drilling engineering assistance; (3) on-site training; (4) post drilling analysis; (5) development of future drilling plans. The long history of geothermal research and development and expertise available in the U.S. could be very beneficial to China's program and could create mutually beneficial business opportunities.

3.6.4 Geological Science Study

The DOE, through the Lawrence Berkeley Laboratory, is supporting a scientific study of the geological mechanisms that are producing the geothermal energy resources at the Tengchong site. By studying noble gas isotopes (argon, helium, neon, krypton, radon, and xenon) in rock samples from the well, it is possible to determine if the heat source is metamorphic or from volcanic magma flow near the surface. This information is important in continental motion studies and for predicting geothermal energy production potential.